Online Appendix

“*Municipal Governments Under the Clean Water Act*”

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September 2025

Appendix A Data Selection & Restrictions

The CWNS surveys from 1972 through 2004, collectively, include information on 40,701 unique treatment plant facilities. My analysis requires identifying all municipal wastewater treatment plants that were operational as of 1972 with observable treatment technology and identifying information. I make the following restrictions to create my sample: I remove all plants with missing treatment type information (i.e., primary or secondary treatment), or 14,808 facilities, leaving 25,893 facilities. This restriction additionally serves to remove planned, future plants from the dataset. I exclude all non-municipal plants including those operated by correctional facilities, hospitals, state or county governments, schools and universities, or tribes, totaling 2,417 facilities. To reduce potential instances of measurement error or misreporting, I exclude wastewater treatment plants that did not meet all of the following criteria: maintains facility type "wastewater treatment plant" as opposed to sewer system, septic, or other (excludes 12.6% of facilities); reports having wastewater treatment plant technology and is recorded as a wastewater treatment facility (excludes 2.8% of facilities); does not downgrade technology type from secondary to primary (excludes 11.6% of facilities), missing facility type information (excludes 0.3% of facilities), facilities located in the contiguous, continental US (excludes 1.2% of facilities), and continues to have a plant in a given year if it had a plant in the prior year (excludes 3.7% of facilities). These additional sample restrictions eliminate approximately 2,462 plants.

I further exclude plants that ceased operation over time or new plants that appear after the 1972 survey by including only facilities listed in each decade and in at least half of the 13 surveys between 1972 and 2004. This restriction further drops 49% of the remaining facilities, leaving 4,495 plants. Thus, my analysis does *not* include cities that built a wastewater treatment plant after the CWA came into effect. This restriction increases the likelihood that compliant and noncompliant cities shared important *ex ante* unobservable characteristics that determine economic growth such as willingness of their taxpayer base to invest in long-lasting infrastructure projects. These sample restrictions serve to reduce measurement error of treatment plant technology and help to ensure that variation across my treatment and control cities is driven primarily by differences in the CWA technology standard, as opposed to cyclical infrastructure degradation, or structural municipal decline. Appendix Table A1 shows descriptive statistics comparing my restricted sample to the full population of municipalities with treatment plants. By utilizing only cities with continuously operating plants, the population size of cities in my analysis is larger, on average, than the mean plant-operating municipality. My sample of cities also has larger budgets, a more educated/higher income population, and they are located slightly closer to coastlines compared to the population of municipalities with plants.

I consider some of the potential limitations associated with the CWNS and Census of Governments data as they apply to my experimental design. These potential limitations will generally tend to bias my results toward a null effect. First, municipal boundaries may not provide the correct spatial extent of pollution abatement effects from wastewater treatment. If the infrastructure's actual impact is more narrow than municipal borders, any perceived benefits of wastewater pollution measured at the this level will be diluted. Conversely, if the actual impacts of surface water pollution extend beyond municipal borders - to downstream cities, for example - the mandated infrastructure will have some impact on *ex ante* compliant cities, again diluting the identified differential across these communities.

Second, multiple municipalities may share a single wastewater treatment plant, particularly if those municipalities are located close together. I can identify the municipality that manages a publicly owned plant from the CWNS data, but I cannot distinguish whether other municipalities are serviced by that plant. This will not compromise the diagnosis of compliant versus noncompliant cities in my design, as I consider only municipalities that are, themselves, the managing authority of a plant. However, to the extent that there is cost-sharing of mandate compliance across communities, my estimates of expenditure changes will be diluted. In Appendix Fig. A1, I compare the plant service population of each plant reported in CWNS to the Census population estimate for the plant's managing municipality and find a correlation coefficient very close to one. This suggests that mis-measurement of the per capita compliance costs borne by municipal residents is likely to be minimal.

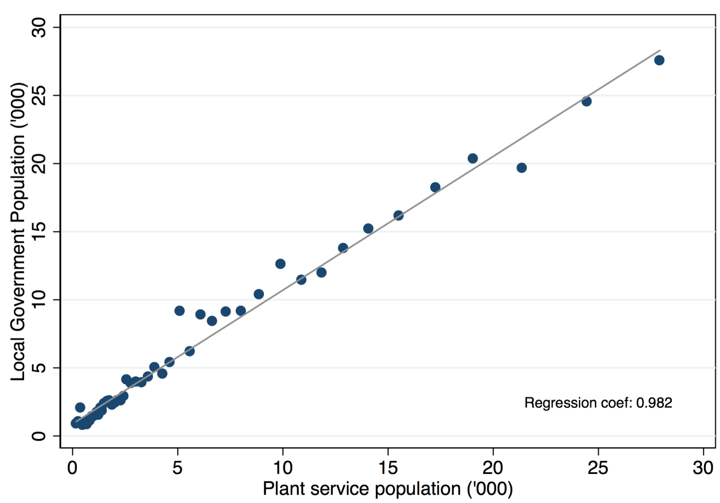


Figure A1: Plant Service Population vs Local Government Population. Source: US Census of Governments; EPA CWNS. Figure shows relationship between local government population as reported by Census of Governments, and service population of its corresponding plant as reported by EPA. Includes 3,226 governments with population less than 30,000. Regression coefficient (r) estimated from Census population =r (Plant population) + e. Each dot represents approximately 60 cities.

Table A1: Comparison of Descriptive Statistics for Sample vs Population of Local Governments with Wastewater Treatment Plants

	Sample	Population of Muni's w/ Treatment Plant	P-value for difference in means
City Characteristics, 1970			
Population	28,725.393	8,993.554	0.000
Share of population with a college degree	0.110	0.096	0.000
Dissolved oxygen (mg/l)	7.807	7.913	0.003
League of Conservation Voters score	44.475	49.898	0.311
County-level labor market, 1970			
County income per capita ($)	23,133.486	21,960.703	0.000
County employment share in manufacturing	0.358	0.355	0.457
County employment share in water-polluting manufacturing	0.142	0.138	0.158
Expenditures per capita, 1967-1972			
Total expenditures ($)	986.046	939.205	0.164
Wastewater	67.873	55.999	0.001
Total other	590.559	574.662	0.144
Public works	120.212	104.651	0.000
Public safety	347.669	361.006	0.135
General & admin.	61.143	60.886	0.877
Health & welfare	24.775	17.186	0.000
Recreation	36.760	30.933	0.000
Revenues per capita, 1967-1972			
Total revenues pc ($)	967.824	906.081	0.001
Intergovernment revenues	166.700	158.022	0.159
Revenues from own sources	801.107	748.107	0.002
Total taxes	377.159	322.218	0.000
Property taxes	296.562	253.181	0.000
Sales & License taxes	80.540	69.110	0.000
Total user fees	91.081	73.952	0.000
Wastewater user fees	25.704	20.265	0.000
Long-term debt outstanding	1,424.501	1,478.070	0.789
Short-term debt outstanding	82.375	53.000	0.000
Geography			
River Population as of 1970 (th.)	11,881.125	13,286.887	0.000
Distance to waterbody (km)	46.925	60.625	0.064
Distance to river mouth ('000 km)	924,974.500	1,316,677.125	0.000
Distance to navigable river (km)	203.667	218.954	0.001
Distance to Ocean (km)	550.745	587.714	0.000
Number of Cities	3,164	6,452	
Panel Frequency	8.201	6.951	
Observations	17,018	53,778	

Note: Second column provides summary statistics for all municipalities with wastewater treatment plants as of 2004, including those that built treatment plants after the 1972 CWA. The list of these municipalities are sourced from the Clean Watershed Needs Survey. P-value denotes significance of difference in means. Dollars in USD 2012 values.

Appendix B Downstream & Upstream Population Calculations

B.1 Downstream Calculation

I construct the downstream population component of the instrument using digital spatial maps sourced from the National Hydrography Dataset Plus of the US Geological Survey (USGS). These maps contain hydrologic information for over 2.6 million stream segments averaging 1 kilometer in length. Every river segment possesses three identifying attributes that allow me to trace out all possible linkages in the US river system: a segment identification code, the code of the immediate upstream river segment, and the code of the immediate downstream river segment. In addition, all segments include an identifier for the terminal point of its river network (i.e., the river "mouth"). The combination of network linkages across segments and terminal point identifiers allows me to identify upstream versus downstream relationships across cities located on the same major river (e.g., the Mississippi) as well as across cities on differing tributaries sharing the same major river basin (e.g., the Illinois and Ohio rivers, which both feed into the Mississippi).

I assign each city centroid to its closest stream segment using GIS software. My criteria for matching cities to a stream segment is to select the six closest stream segments to a city centroid and assign the city to the stream segment with the lowest stream order. This approach accounts for the tendency of cities to divert wastewater effluent into the main river segment closest to their city as opposed to a small tributary.

I then calculate each city's cumulative downstream population through a recursive "search tree" algorithm as follows: I first find the terminal point, or the mouth, of each river network and assign this segment a downstream population of $x_i = 0$ and a current population of x_j equal to the population of a city at that mouth, if one exists. Notably, I utilize the universe of municipal governments for this process, not just those in my sample of cities with a treatment plant. This ensures that any city downstream can exert pressure on an upstream polluter, not just those in my sample. Moving upstream along stream segments, indexed by j for current and i for the relative downstream segment, I sum the population x_i of any cities located along those segments until a branching occurs. The branch point is again treated as a temporary "river mouth" with a downstream population of $\sum_0^i x_i$, and the process repeats itself until the source ($j = N$) of the river is reached, with a total downstream population of $x_j + \sum_0^N x_i$.

B.2 Upstream Calculation

I use digital maps on river networks from the National Hydrography Dataset of the USGS to observe, for every stream segment i in the contiguous US, which stream segment is immediately upstream and immediately downstream of that segment i. This process requires that I reverse the recursive approach outlined in Appendix B.1 as follows: I first find the start point, or headwaters, of each river and assign this segment an upstream population of $u_i = 0$ and a current population of u_j equal to the population of any city at that segment, if one exists. Moving downstream along connecting stream segments, indexed by j for current and i for the relative upstream segment, I sum the populations u_i of any cities located upstream of segment j until a branching occurs. Unlike the downstream calculation approach, here I must account for the multitude of instances where several headwaters enter the same branch point as I follow a network downstream. Thus, at a given branch point, I temporarily "hold" the upstream population value for one stream network and "wait" for the recursive process from other streams above the branch point to arrive at that same branch point. Once all distinct stream networks arrive at their common branch point, I aggregate the upstream populations of each stream network so that a given branch point has an upstream population of $\sum_N^i u_i$ and the process repeats itself until the mouth of the river ($j = 0$) is reached with a total upstream population of $u_j + \sum_N^i u_i$. As in the downstream calculation, I utilize the universe of municipal governments for this process, not just those in my sample of cities with a treatment plant. This ensures that spillovers from upstream can originate from any city, not just those with a treatment plant. Appendix Figure A2 shows the spatial distribution of upstream populations for each municipality, aggregated to the county level.

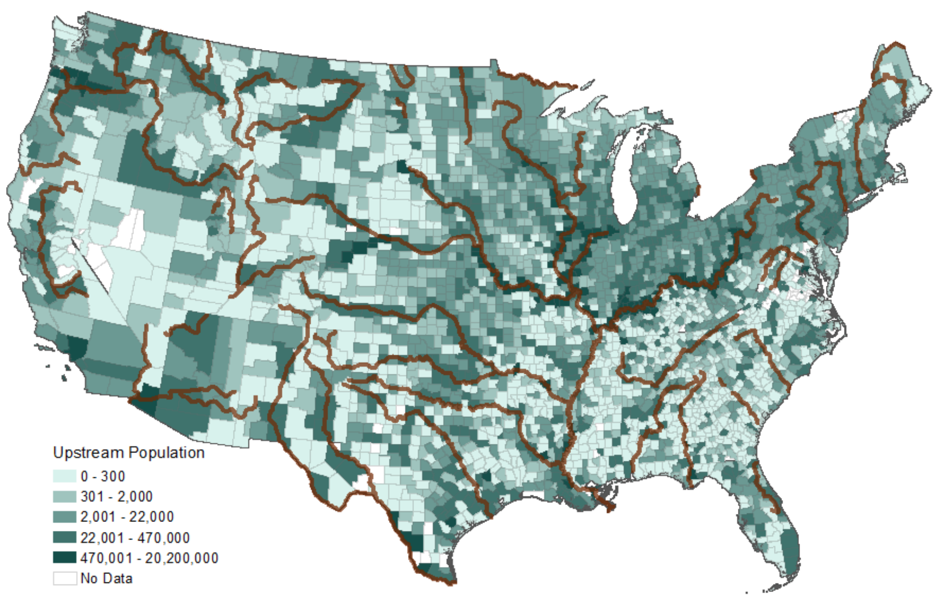


Figure A2: Mean Municipal Upstream Population Size by County, 1970. Source: USGS, Census, author's calculations.

Note: Figure shows county-level averages of city upstream population as of 1970. Only major rivers shown for exposition purposes. The spatial distribution exhibits a marked checker board pattern relative to that of mean downstream populations shown in Fig. 2. The greater heterogeneity in upstream population within a small geographic area is a result of the positive correlation between branching and being positioned further upstream on a network. If two cities are on separate branches of the same network, those two cities are likely to have very similar downstream populations (since their respective branches will converge), but can have vastly different population counts upstream.

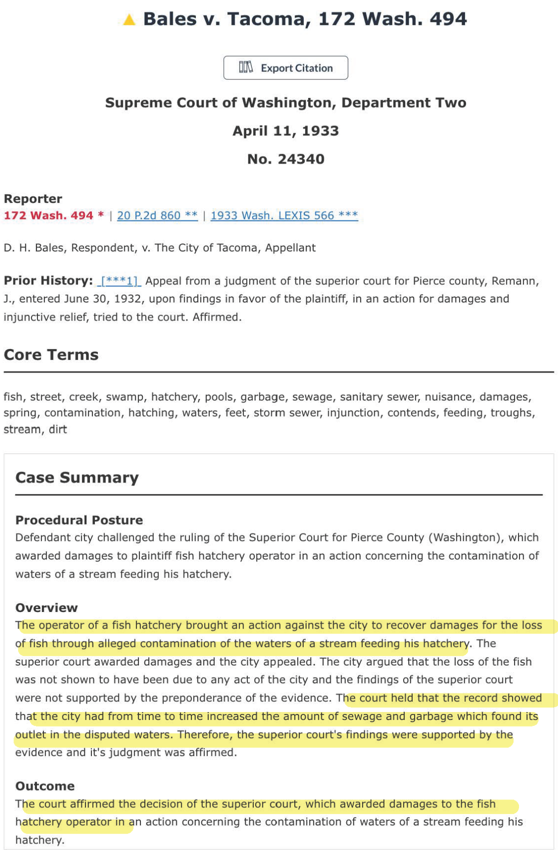
Appendix C Construction of the State Case Index

This section outlines details on how I constructed the State Case Index. All cases are sourced from the *NexisUni* database, accessible through the UW Madison Library system. From this database, I implemented searches for all state and local-level cases that occurred between January 1, 1900 and December 31, 1947. I chose this time frame to strike a balance between observing cases late enough to overlap with the initial construction of wastewater treatment plants in many US cities at the turn of the century, but early enough to avoid the influence of early federal water pollution control laws (the first federal water pollution control law was enacted in 1948). In addition to this time frame, I filtered cases to only those that included at least one of the following combination of search terms: (1) "sewer", "nuisance", and "water"; (2) "water", "contam!" and "nuisance"; or (3) "water" and "pollut!" in the same paragraph. In order to have at least three cases for each state, I also implemented further searches for cases in Arizona, Colorado, Delaware, Florida, Nevada, Maine, New Mexico, Louisiana, South Dakota, and Wyoming. These states gained statehood either very recently or a long time ago relative to the other US states, both of which mean that coverage of state case hearings on water pollution during 1900 to 1947 is relatively sparse.

To broaden my search criteria for these states, I used the following search terms: (4) "river" and "waste" in the same paragraph, (5) "river" and pollut!" in the same paragraph; and (6) "water" and "pollut!" in the same paragraph. For the states Delaware, New Mexico and Nevada, I further broadened the search for cases that include the term (6) "Riparian". Because I still had very few observations for Delaware, New Mexico, and Nevada, I supplemented my search results from *NexisUni* with searches in the *Westlaw* database for the terms (7) "water" and "pollut!"; as well as (8) "water" and "sewer". For the *Westlaw* searches, it was necessary to extend my search date back to January 1, 1886 in order to obtain enough observations for the state of Delaware.

From over 1,000 candidate cases, I excluded cases that were not affirmed by the state court, were not related to water nuisances (such as cases about death or injury from drowning); or were pre-emptive cases (for instance, cases where the plaintiff wished to sue for plans to build a sewer system near their property, but for which the plaintiff had not yet incurred any pollution or nuisance). After removing duplicate search results, this criteria resulted in a total of 432 cases.

From the candidate cases, I identified the "pollutee" and the "polluter" and which of these two parties won their case. In about 67% of cases, the "pollutee" won their case. As an example of the cases used to create the index, below I show a search result where the appellate court ruled in favor of the "pollutee" (Appendix Figure A3) and another where the ruling was in favor of the "polluter" (Appendix Figure A4).



▲ Bales v. Tacoma, 172 Wash. 494

Export Citation

Supreme Court of Washington, Department Two

April 11, 1933

No. 24340

Reporter
172 Wash. 494 * | 20 P.2d 860 ** | 1933 Wash. LEXIS 566 ***

D. H. Bales, Respondent, v. The City of Tacoma, Appellant

Prior History: [***1] Appeal from a judgment of the superior court for Pierce county, Remann, J., entered June 30, 1932, upon findings in favor of the plaintiff, in an action for damages and injunctive relief, tried to the court. Affirmed.

Core Terms

fish, street, creek, swamp, hatchery, pools, garbage, sewage, sanitary sewer, nuisance, damages, spring, contamination, hatching, waters, feet, storm sewer, injunction, contends, feeding, troughs, stream, dirt

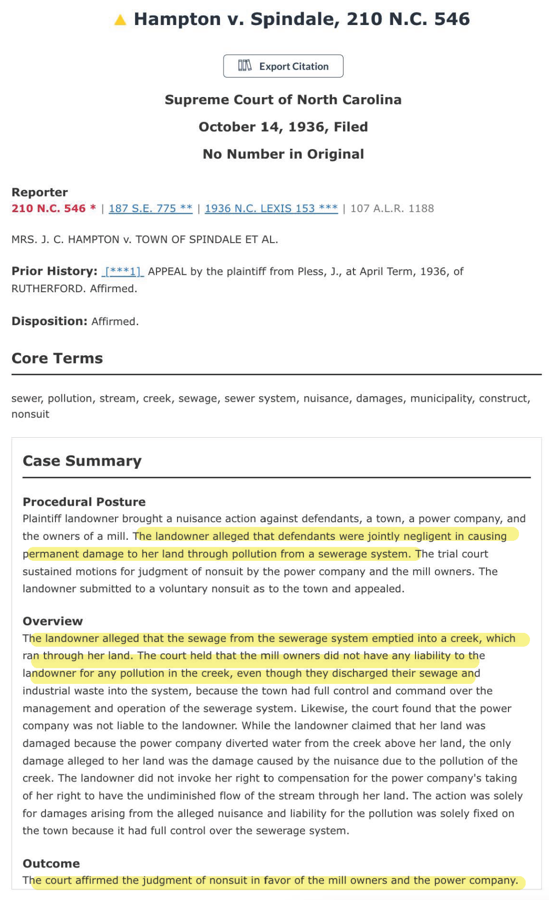
Case Summary

Procedural Posture
Defendant city challenged the ruling of the Superior Court for Pierce County (Washington), which awarded damages to plaintiff fish hatchery operator in an action concerning the contamination of waters of a stream feeding his hatchery.

Overview
The operator of a fish hatchery brought an action against the city to recover damages for the loss of fish through alleged contamination of the waters of a stream feeding his hatchery. The superior court awarded damages and the city appealed. The city argued that the loss of the fish was not shown to have been due to any act of the city and the findings of the superior court were not supported by the preponderance of the evidence. The court held that the record showed that the city had from time to time increased the amount of sewage and garbage which found its outlet in the disputed waters. Therefore, the superior court's findings were supported by the evidence and it's judgment was affirmed.

Outcome
The court affirmed the decision of the superior court, which awarded damages to the fish hatchery operator in an action concerning the contamination of waters of a stream feeding his hatchery.

Figure A3: Example case: Pollutee Wins



▲ Hampton v. Spindale, 210 N.C. 546

Export Citation

Supreme Court of North Carolina

October 14, 1936, Filed

No Number in Original

Reporter
210 N.C. 546 * | 187 S.E. 775 ** | 1936 N.C. LEXIS 153 *** | 107 A.L.R. 1188

MRS. J. C. HAMPTON v. TOWN OF SPINDALE ET AL.

Prior History: [***1] APPEAL by the plaintiff from Pless, J., at April Term, 1936, of RUTHERFORD. Affirmed.

Disposition: Affirmed.

Core Terms

sewer, pollution, stream, creek, sewage, sewer system, nuisance, damages, municipality, construct, nonsuit

Case Summary

Procedural Posture
Plaintiff landowner brought a nuisance action against defendants, a town, a power company, and the owners of a mill. The landowner alleged that defendants were jointly negligent in causing permanent damage to her land through pollution from a sewerage system. The trial court sustained motions for judgment of nonsuit by the power company and the mill owners. The landowner submitted to a voluntary nonsuit as to the town and appealed.

Overview
The landowner alleged that the sewage from the sewerage system emptied into a creek, which ran through her land. The court held that the mill owners did not have any liability to the landowner for any pollution in the creek, even though they discharged their sewage and industrial waste into the system, because the town had full control and command over the management and operation of the sewerage system. Likewise, the court found that the power company was not liable to the landowner. While the landowner claimed that her land was damaged because the power company diverted water from the creek above her land, the only damage alleged to her land was the damage caused by the nuisance due to the pollution of the creek. The landowner did not invoke her right to compensation for the power company's taking of her right to have the undiminished flow of the stream through her land. The action was solely for damages arising from the alleged nuisance and liability for the pollution was solely fixed on the town because it had full control over the sewerage system.

Outcome
The court affirmed the judgment of nonsuit in favor of the mill owners and the power company.

Figure A4: Example case: Polluter Wins

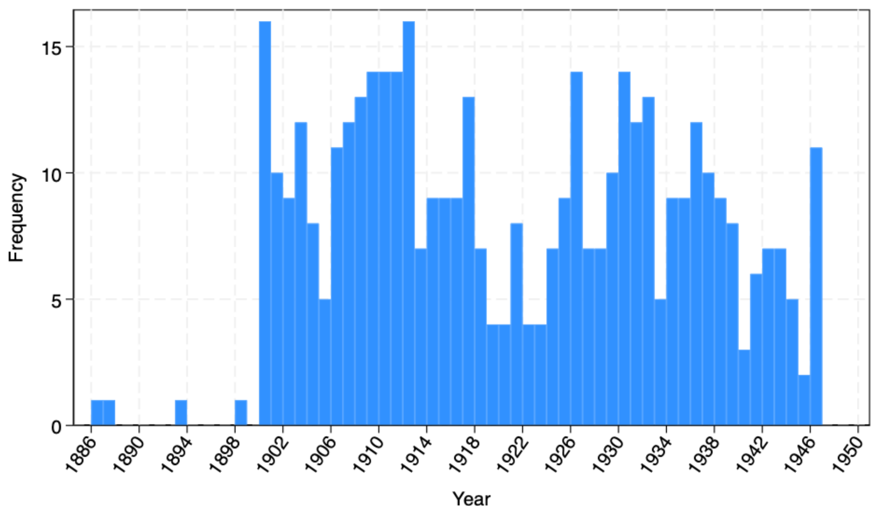


Figure A5: Frequency of Water Nuisance Cases by Year. (Source: NexisUni Database)

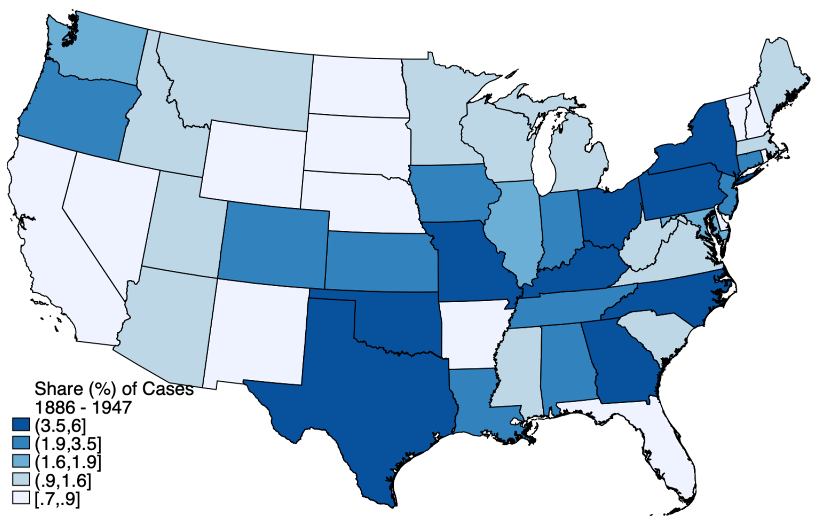


Figure A6: Share of Water Nuisance Cases, 1886-1947. (Source: NexisUni Database. Categories based on quantiles.)

Appendix Figures A5 and A6 show the temporal and geographic variation of when and where the cases in my sample occured. Most cases occurred after 1900, with notable dips during world war periods. Appendix Figure A6 shows that at least three hearings occurred in each state between 1886 and 1947, but water-related tort cases were most likely to occur in more populous states, like Texas, New York, and Pennsylvania, as well as states with major rivers like Ohio and Missouri. Figure 3 shows variation in the State Case Index across states. Comparing this Figure to that of Appendix Figure A6, it is evident that some states with more hearings also have a higher index (for instance, Missouri, New York, Pennsylvania). Yet, there are several instances where the opposite holds. Texas, Oregon, and Georgia are notable examples. This quells some concern of bias from measurement error because the index value does not appear highly correlated with the number of cases per state.

Table A2: Correlates of State Case Index

	(1) Pre-CWA Statute (=1)	(2) State Primacy Index	(3) Water Regulation Index	(4) Naural Resources Budget Share (1950s)	(5) Legal Budget Share (1950s)
State Case Index	0.027	-0.011	0.001	-0.001	0.000
	(0.027)	(0.082)	(0.001)	(0.001)	(0.000)
Dep.Var. Mean	0.875	2.812	0.023	0.039	0.008
Region FE	Y	Y	Y	Y	Y
Observations	48	48	48	48	48

The dependent variables are listed in column headers. Data includes one observation per US state (excluding Alaska and Hawaii).“Pre-CWA Statute” equals 1 if the state had any law pertaining to water pollution regulation as of 1948 (Figure 1a, Van Antwerpen, 1948).“State Primacy Index” ranges from 1 to 5 based on the year that the state obtained primacy enforcement authority under the CWA (Sigman 2005). “Water Regulation Index” measures the degree of water pollution regulation in the state as of 1948 and is comprised of 5 components:(1) whether the state had any law regulating discharge, (2) whether treatment plant plans require state approval, (3) whether there are state imposed penalties for noncompliance (4) whether industries are exempt from regulation; and (5) whether the state applies a hierarchy of treatment requirements based on the stream type. All values are sourced from Figure 1a of Van Antwerpen (1948). “NatRes Budget Share”measures the average share of state annual expenditures on natural resources from 1951-1959. “Legal Budget Share” measures the average share of state annual expenditures on judicial and legislative expenditures from 1951 to 1959. Both variables are sourced from Lueck and Parker(2025). The “Region” fixed effect includes an indicator for 8 US regions. Standard errors are robust. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A3: Pretrends of City Characteristics by Compliance Status and Instrument

Compliance Status:	Primary as of 1972		Instrumented	
	(1)	(2)	(3)	(4)
Total Expenditures pc	67.628	(122.820)	-1131.250	(1721.707)
Sewerage Expenditures pc	-63.984***	(22.434)	144.039	(207.608)
Sewerage CapExp pc	-62.511***	(22.058)	158.585	(207.068)
Sewerage OperExp pc	-1.147	(2.381)	-6.295	(36.300)
Other Expenditures pc	36.300	(39.028)	-156.816	(560.854)
Public Safety pc	5.136	(4.064)	-29.087	(61.330)
Public Works pc	4.155	(32.149)	77.174	(478.397)
G&A pc	9.388	(8.422)	-158.379	(119.473)
Health & Welfare pc	11.993	(7.788)	-57.040	(131.166)
Rec pc	3.256	(5.014)	10.515	(48.205)
Total Revenues pc	137.493	(115.855)	-1143.763	(1667.752)
Fed grants pc (all)	-15.134	(10.182)	220.885	(141.653)
Total Own Revenues pc	134.822	(114.076)	-1230.761	(1652.875)
Total User Fees pc	9.826	(9.355)	-183.601	(157.085)
WW User Fees pc	-8.681***	(2.873)	61.897	(51.550)
Total Tax Revenues pc	11.879	(14.043)	-94.414	(306.897)
Property Tax Revenues pc	12.982	(12.875)	-243.010	(308.189)
Sales Tax Revenues pc	-1.014	(5.276)	148.263	(91.293)
LT Debt pc	2126.797	(2182.407)	-30068.081	(32222.841)
ST Debt pc	-29.103	(20.765)	-491.999	(320.335)
Dissolved Oxygen† (mg/l)	0.033	(0.045)	-0.913**	(0.368)
Ln(Population)*	-0.077***	(0.024)	0.325	(0.214)
Controls	Y		Y	
Observations	2792		2792	

Note: Table provides estimates of β from: $f_{it} = \beta(\text{Primary}_i \times \tilde{POST}_t) + \mu_i + \tau_t + \epsilon_{it}$ where f_{it} is an outcome for city i in year t; $\tilde{POST}$ is an indicator equal to 0 in 1967 and 1 in 1972; and β is the mean difference in pre-CWA growth from 1967 to 1972 among ex ante compliant cities relative to non compliant cities. Column (1) reports estimates of β when "Primary" equals 1 if a city had only primary treatment as of 1972, column (2) is the respective standard errors. Column (3) reports estimates of β when I instrument for "Primary" using the Downstream Population and the State Case Index, column (4) is the respective standard errors. The sample includes only pre-CWA years, 1967 and 1972. † Dissolved Oxygen includes annual data from 1961 to 1974, where $\tilde{POST} = 1$ in for years 1973 and 1974 (as in Figure 5). Includes 29,036 observations. *Ln(Population includes decades from 1930 through 1970, where $\tilde{POST} = 1$ in 1970 (as in Figure 5). Includes 14,066 observations. "Controls" include city and year fixed effects, distance to the ocean-by-year fixed effects, and watershed-by-year fixed effects. Standard errors are clustered by city. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix D Parallel Trends Sensitivity Analysis

This section implements the "honest" approach to parallel trends proposed by Rambachan & Roth (2023). The primary concern in my identification strategy is the existence of secular trends that differ systematically across treated versus control municipalities, such as confounding changes in local economic conditions or amenity growth. Because I suspect that any differences in trends between treated and control municipalities would have evolved smoothly over time, I test for the existence of pre-trends against a smoothness restriction as follows:

$$\Delta_{SD} \equiv \{\delta : |(\delta^{t+1} - \delta^{t}) - (\delta^{t} - \delta^{t-1}| \leq M\}$$

where Δ_{SD} measures the "second difference" of the difference in trends δ across pre and post-treatment time periods. M governs the amount by which the slope of δ can change between consecutive periods. In other words, M measures by how much the slope of the pre-trend is allowed to change in post-treatment periods.

In Appendix Figure A7 below, I show the sensitivity of my dissolved oxygen and population event study results to various deviations from the linear extrapolation assumption (where $M = 0$). Panels (a) and (c) replicate the event study results from Figure 5 while panels (b) and (d) report the sensitivity of these results to the linear extrapolation of the pre-event coefficients using the Rambachan & Roth (2023) approach. In red, I show the 95% confidence interval of the treatment effect (averaging all post-treatment periods), while in blue I show the 95% confidence interval when allowing for violations of the pre-period parallel trends up to a parameter M.

For **dissolved oxygen**, the coefficient would remain significant up to about $M = 0.02$, meaning my results would remain significant even if I allow for post-treatment deviations from the linear extrapolation of the estimated pre-trend of up to 0.02 percentage points. The estimated slope of the pre-trend from 1963 to 1969 is about 0.033. Consequently, I can reject a null effect unless I am willing to allow for deviations from a linear extrapolation of the pre-period trend to be off by more than 60% (0.02/0.033). In summary, this analysis confirms that the CWA infrastructure mandate had sizeable and statistically significant positive impacts on local water quality, even after allowing for significant differences in secular trends across treated and control municipalities.

For **population**, the confidence intervals cannot rule out a null effect when allowing for linear violations of parallel trends. I provide some explanation for this. First, the confidence intervals in the pre-period are large relative to the post-treatment effects. The Rambachan & Roth (2023) method incorporates these larger standard errors when setting bounds on an hypothetical pre- trend. Thus event studies with larger pre-treatment standard errors will be less likely to rule out a null effect when applying the Rambachan & Roth (2023) method even if the pre-treatment point estimates do not exhibit sizeable trends, as in my case. As Rambachan & Roth (2023) state, "our inference methods account for both statistical uncertainty (we can only noisily estimate the true pre-trend) as well as 'identification uncertainty'..."

A second reasoning is that the post-treatment trend appears to increase gradually over time rather than exhibit a sharp break. While this may be evidence against a causal impact of the CWA on population growth, a more nuanced interpretation is that population effects to any marginal treatment are very likely to exhibit a gradual trend. My interpretation of the growth results is that they manifest gradually as a consequence of changes in amenities, local public goods, and broader capitalization effects of the CWA treatment. Thus, population event studies around marginal treatments are unlikely to pass the Rambachan & Roth (2023) test. Given that I cannot rule out that the post-treatment coefficients are are continuation of pre-treatment trends, I interpret the population growth results with caution.

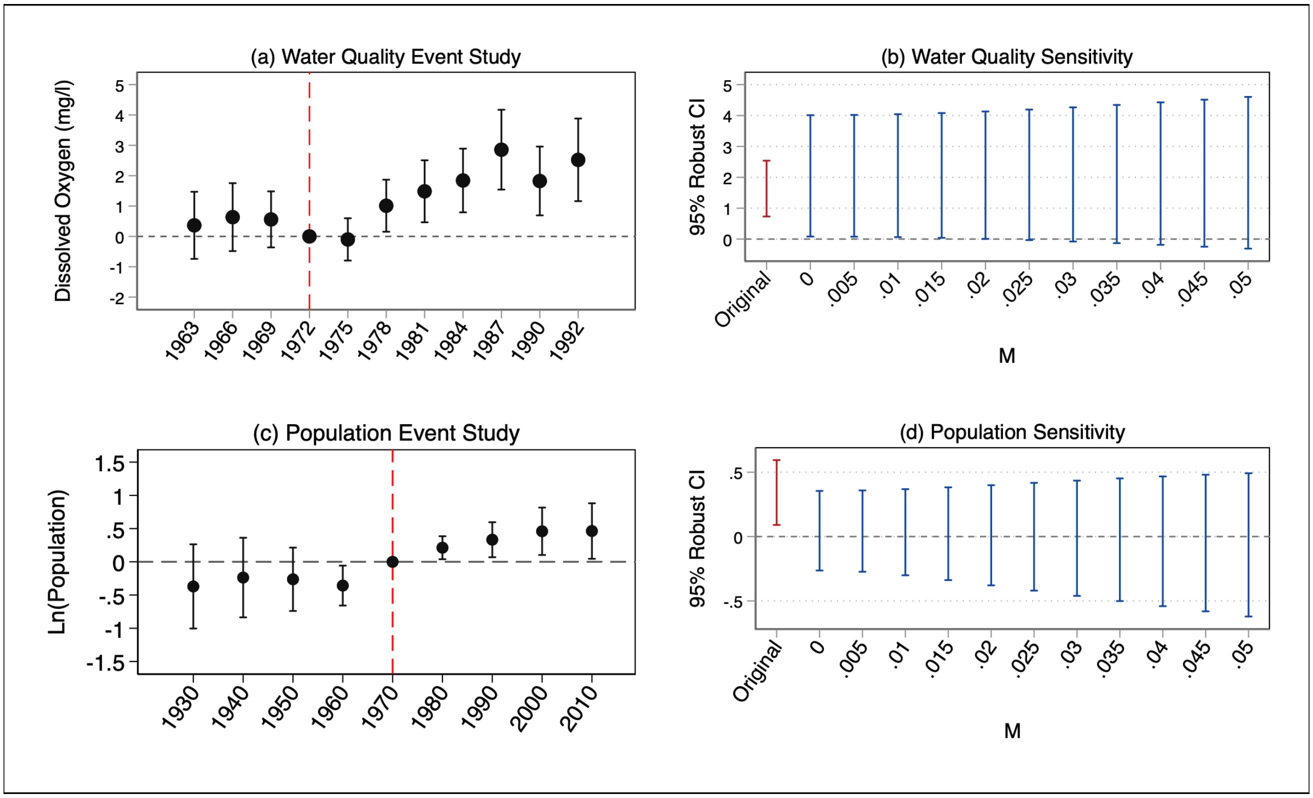


Figure A7: Parallel trends sensitivity analysis —breakdown points for post-CWA average treatment coefficients.

Note: This figure assesses the plausibility of the parallel trends assumption. The left two panels (a) and (c) replicate the event study results from Figure 5. The right two panels (b) and (d) report the sensitivity of these results to the linear extrapolation of the pre-event coefficients using the honest approach to parallel trends from Rambachan & Roth (2023). These panels report 95% confidence intervals for the average of all post-CWA coefficients when I allow the slope of the pre-trend coefficients to change by no more than M across consecutive periods.

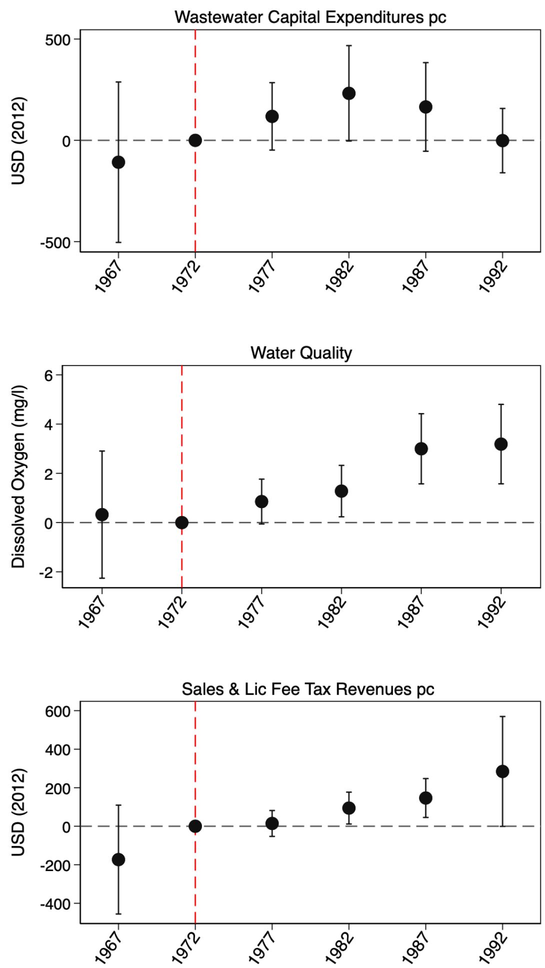


Figure A8: Dynamic Estimates of CWA Mandate Effects.

Notes: Figure plots estimates of δ_t from Eq. 4: $y_{ist} = \sum_{t='67(\ni'72)}^{'92} \delta_t(\widehat{P_i \times D_t}) + \mathbf{X_i}\theta_t + \tau_t + \nu_i + \varepsilon_{ist}$. δ_t is the difference between control and treated cities in each of three outcomes (y_{irt}=wastewater capital expenditures per capita, dissolved oxygen, and sales and license fee tax revenues per capita) from year t relative to 1972. Treatment status P_i is instrumented using downstream population and the State Case Index. Regressions include all controls listed in column 6 of Table 2. Bands show 95% confidence intervals. Robust standard errors clustered at the city level.

Table A4: Triple Difference-in-Differences: Effect of CWA Mandate on Downstream Water Quality

	Triple DID			
	(1)	(2)	(3)	(4)
Primary'72 x Post x Down	0.354*	0.397*	0.368*	0.350*
	(0.214)	(0.206)	(0.189)	(0.212)
Primary'72 x Post	-0.210	-0.278*	-0.195	-0.134
	(0.155)	(0.155)	(0.135)	(0.142)
Baseline Mean (mg/l)	7.46	7.46	7.38	7.38
Controls	Y	Y	Y	Y
City FE	Y	Y		
Plant FE			Y	Y
DS FE				
DS x Year FE		Y		Y
DS x City FE		Y		
DS x Plant FE				Y
Observations	6066	5711	9461	9068

Note: The outcome variable is dissolved oxygen (mg/l). Table reports estimates of β_{triple} and α_1 from the following triple difference design: $y_{imt} = \beta_{triple}(\text{Primary}_i \times POST_t \times d_{m,i}) + \alpha_1(\text{Primary}_i \times POST_t) + \alpha_2(\text{Primary}_i \times d_{m,i}) + \alpha_3(POST_t \times d_{m,i}) + \alpha_4(d_{m,i}) + \gamma f(k_{i,m}, d_{m,i}) + \mathbf{X_i}\gamma_t + \nu_i + \tau_t + \epsilon_{imt}$ where i indexes a municipality (in columns 1 and 2) or plants (in columns 3 and 4); t indexes a year, and m indexes a monitor site. d is an indicator that equals 1 if a monitor is downstream. ν are fixed effects for cities or plants. $f(k_{i,m}, d_{m,i})$ is a polynomial function including the distance k from the monitor m to city (or plant) i, an interaction of k with d and the quadratics of both. Each specification includes a different set of fixed effects as noted in the table. "DS" stands for "Downstream". "Controls" include all controls listed in Table 2, column(6). Standard errors in clustered by city. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A5: Population Growth and Exposure to Upstream Spillovers

	(1)	(2)	(3)	(4)
Primary'72xPost	0.272**	0.319**	0.328**	0.328**
	(0.128)	(0.136)	(0.139)	(0.139)
x 1 SD Upstream Population	-0.027***	-0.040***		
	(0.009)	(0.010)		
1 SD Upstream Population x Post			-0.078***	0.100
			(0.024)	(0.110)
x (base pop < 90th pctl)				-0.212*
				(0.113)
Upstream Pop. Non-CWA		Y	Y	Y
Observations	17006	14247	14247	14247

Note: The dependent variable is ln(population). Table reports estimates of β_{IV} from Eq. 3 that includes an interaction of the treatment effect and exposure to populations upstream. All specifications include all controls listed in Tab. 2, column(6). Columns (2) through (4) include only cities with upstream populations that were not affected by the CWA. "base pop < 90th pctl" is an indicator equal to 1 if a city's average population between 1967 and 1972 was below the 90th percentile. Standard errors clustered by city. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A6: Descriptive Statistics Across Large versus Small Local Governments

	Pre-CWA Population > 90th pctl	Pre-CWA Population < 90th pctil	P-value for difference in means
City Characteristics, 1967-1970			
Population	167,366.703	6,786.469	0.000
Share of population with a college degree	0.117	0.109	0.009
Dissolved oxygen (mg/l)	7.512	7.854	0.000
League of Conservation Voters score	47.061	44.065	0.006
County-level labor market, 1970			
County income per capita ($)	25,279.689	22,793.865	0.000
County employment share in manufacturing	0.336	0.362	0.000
County employment share in water-polluting manufacturing	0.125	0.144	0.001
Expenditures per capita, 1967-1972			
Total expenditures ($)	1,464.279	910.369	0.000
Wastewater	91.607	64.117	0.000
Total other	874.094	545.692	0.000
Public works	212.573	105.597	0.000
Public safety	412.530	337.405	0.000
General & admin.	70.175	59.714	0.007
Health & welfare	97.989	13.189	0.000
Recreation	80.827	29.787	0.000
Revenues per capita, 1967-1972			
Total revenues pc ($)	1,407.720	898.213	0.000
Intergovernment revenues	285.717	147.866	0.000
Revenues from own sources	1,122.002	750.328	0.000
Total taxes	601.376	341.679	0.000
Property taxes	466.219	269.715	0.000
Sales & License taxes	135.155	71.898	0.000
Total user fees	166.309	79.177	0.000
Wastewater user fees	42.194	23.095	0.000
Long-term debt outstanding	1,852.013	1,356.850	0.184
Short-term debt outstanding	205.474	62.896	0.000
Number of Cities	314	2,850	

Note: All variables measured as means in 1967 and 1972. P-value denotes significance of difference in means.
90th percentile of pre-CWA municipal population is 27,542. Dollars in USD 2012 values.

Table A7: Effect of CWA Mandate on Local Government Budgets by Pre-CWA Population Size

Expenditures Per Capita	Total	Wastewater			Other					
		Total	Capital	Operating	Total	Public Safety	Public Works	Gen Admin	Welfare	Rec
Primary'72xPost	144.758	227.151***	194.700***	31.898	128.561	-34.129	181.844	13.371	-18.007	-14.517
	(349.821)	(84.964)	(75.476)	(27.391)	(184.212)	(54.482)	(163.581)	(24.691)	(39.875)	(16.757)
x (base pop < 90th pctl)	-201.810	-62.012*	-67.380**	4.941	107.112	-14.475	103.317	18.672	3.083	-3.485
	(133.379)	(33.534)	(28.793)	(11.759)	(92.047)	(13.683)	(73.909)	(12.920)	(29.777)	(11.980)
Revenues Per Capita	Total Revenues			User Fees		Taxes			Debt	
	Total	Federal Grants	Own	Total	Wastewater	Total	Property	Sales & License	Long Term	Short Term
Primary'72xPost	487.731	168.003***	392.560	-171.181	60.718**	229.733**	62.990	166.958***	-3609.212	-422.810**
	(344.978)	(58.957)	(318.310)	(106.896)	(28.202)	(109.805)	(89.721)	(58.379)	(4768.638)	(166.553)
x (base pop < 90th pctl)	-139.192	-15.666	4.426	7.627	23.545*	-51.272	-39.302	-12.269	-846.155	272.044***
	(129.928)	(36.481)	(97.999)	(49.563)	(13.363)	(46.940)	(34.629)	(30.770)	(591.948)	(99.141)
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	17018	17018	17018	17018	17018	17018	17018	17018	17018	17018

Note: Dependent variables are in 2012 dollars per capita. Table reports estimates of β_{IV} from Eq. 3. "Controls" include all controls listed in Table 2, column(6). "(base pop $<$ 90th pctl)" is an indicator equal to 1 if the local governments average population between 1967 and 1970 was below the 90th percentile (27,542). Standard errors clustered by city. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

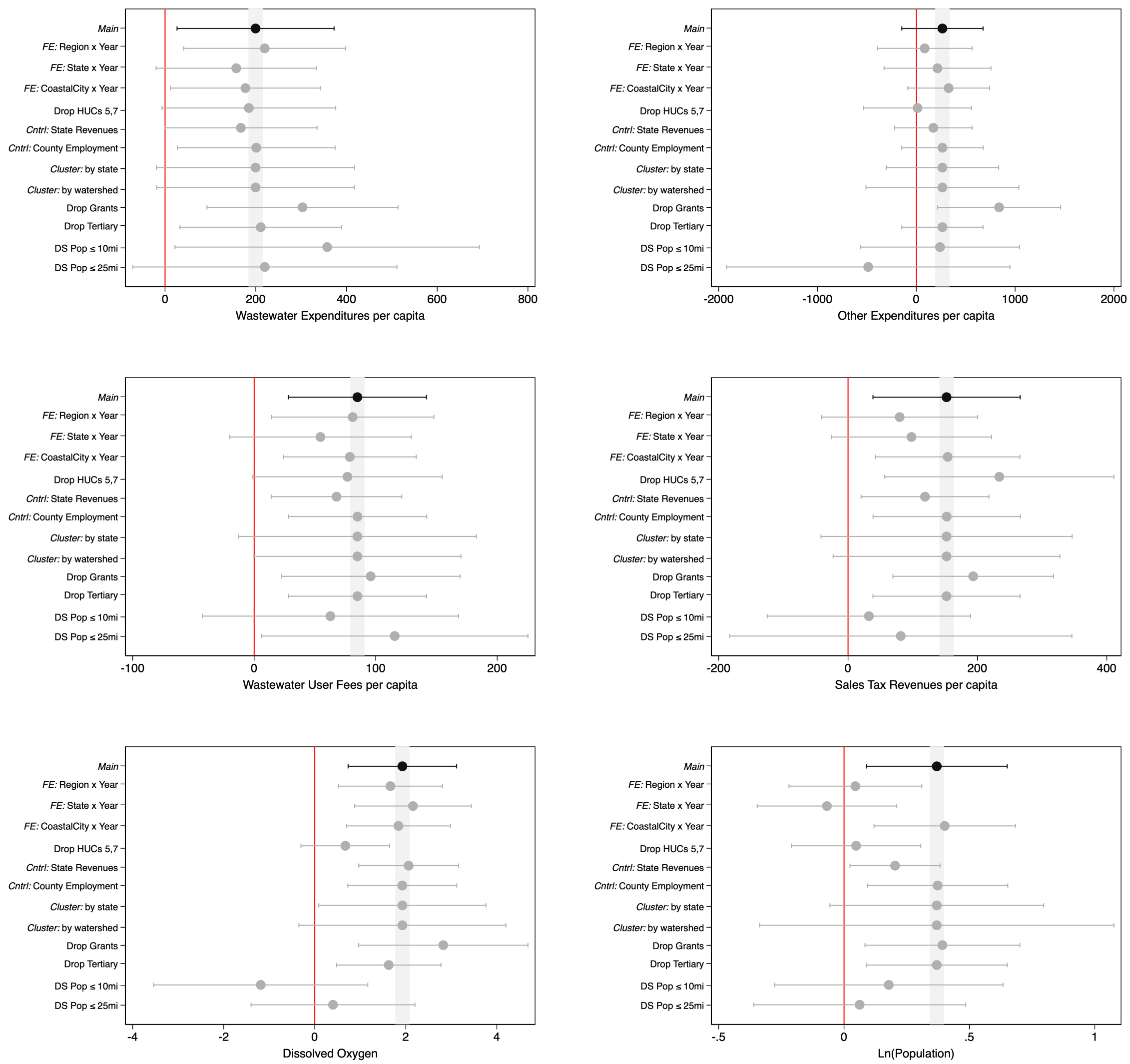


Figure A9: Specification Sensitivity of CWA Mandate Effect.

Note: Figure plots estimates of β_{IV} from Eq. 3 under alternative specifications. Each point estimate and 95% confidence interval band are generated from a distinct regression and each panel shows a different outcome: wastewater expenditures per capita ($), other expenditures per capita ($), wastewater user fees per capita ($), sales & license fee tax revenues per capita ($), dissolved oxygen (mg/l), and ln(population). Point estimates labeled *Main* are estimated using all controls in Table 2 column (6), and are reported in Table 3 and Table 4 col (4). Point estimates labeled *FE* include fixed effects as described. "Drop HUCs 5,7" excludes cities in the Ohio and Mississippi watersheds. Point estimates labeled *Cntrl* include annual controls as described. Point estimates labeled *Cluster* use standard errors clustered at the geographic unit described. "Drop Grants" excludes *ex ante* compliant cities that received a CWA grant prior to 1992. "Drop Tertiary" excludes *ex ante* compliant cities that upgraded from secondary to tertiary treatment levels prior to 1992. "DS Pop $\leq$ 10mi" and "DS Pop $\leq$ 25 mi" use as instruments populations (measured as of 1970) within 10 and 25 miles downstream, respectively. All specifications include all controls listed in Table 2 column (6).

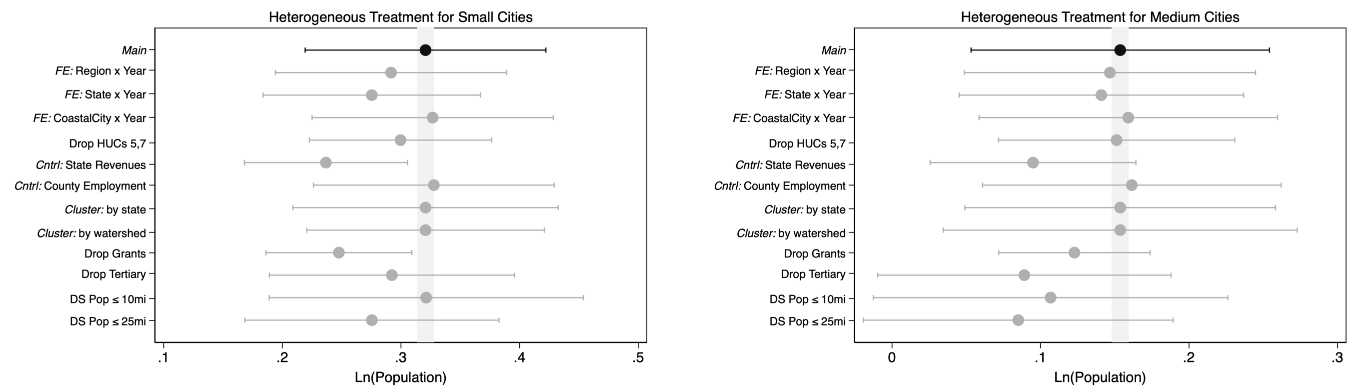


Figure A10: Heterogeneous Ln(Population) Effects by City Size with Specification & Instrumental Variable Sensitivity of CWA Mandate.

Notes: Figure plots estimates of α_s and α_m, the heterogeneous effects of the CWA on municipal ln(population) by city size from a version of Eq. 4: $y_{ist} = \beta_{IV}(P_i \times \widehat{POST}T_t) + \alpha_s(P_i \times \widehat{POST}T_t \times I_s) + \alpha_m(P_i \times \widehat{POST}T_t \times I_m) + \mathbf{X_i}\theta_t + \tau_t + \nu_i + \varepsilon_{ist}$ where I_s and I_m are indicators equal to 1 if a city's 1967-1972 population was below the 75th percentile, and between the 75th and 90th percentiles, respectively. The left panel plots estimates of α_s and the right panel plots estimates of α_m. For each specification, α_s and α_m are estimated within the same regression. Point estimates labeled *Main* are from the specification reported in Table 4 col (4). Point estimates labeled *FE* include fixed effects as described. "Drop HUCs 5,7" excludes cities in the Ohio and Mississippi watersheds. Point estimates labeled *Cntrl* include annual controls as described. Point estimates labeled *Cluster* use standard errors clustered at the geographic unit described. "Drop Grants" excludes *ex ante* compliant cities that received a CWA grant prior to 1992. "Drop Tertiary" excludes *ex ante* compliant cities that upgraded from secondary to tertiary treatment levels prior to 1992. "DS Pop $\leq$ 10mi" and "DS Pop $\leq$ 25 mi" use as instruments populations (measured as of 1970) within 10 and 25 miles downstream, respectively. All specifications in all panels include all controls listed in Table 2 column (6).